

FORM PTO-1390

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

09/719874

ATTORNEY DOCKET NUMBER <b>IN-5439</b>	U.S. APPLICATION NO (IF KNOWN SEE 37 RR 15)	
INTERNATIONAL APPLICATION NO. <b>PCT/EP 99/04370</b>	INTERNATIONAL FILING DATE <b>23/06/1999 (23.06.99)</b>	PRIORITY DATE CLAIMED <b>27/06/1998 (27.06.98)</b>
TITLE OF INVENTION: <b>TAYLOR REACTOR FOR MATERIALS CONVERSION IN THE COURSE OF WHICH A CHANGE IN VISCOSITY v OF THE REACTION MEDIUM OCCURS</b>		
APPLICATION(S) FOR DO/EO/US: <b>Hans-Ulrich MORITZ, Sabine KOSSAK, Jessica LANGENBUCH, Heinz-Peter RINK and Werner Alfons JUNG</b>		

**Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:**

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371 (b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ have been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(C)(2)).
7. ☒ Amendment to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annex to the International Preliminary Examination Report under PCT Article 36

**Items 11. to 16. below concern other document(s) or information included:**

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included
13. ☒ A FIRST preliminary amendment.  
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A Change of power of attorney and/or address letter.
16. ☒ Other items or information:

**A copy of the cover sheet from the PCT Published Application**

I hereby certify that the attached correspondence is being deposited with the United States Postal Service in an envelope as "Express Mail Post Office to Addressee" Mailing Label No. **EK894924595US** addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231 on December 18, 2000.

*Marjorie Ellis*

Marjorie Ellis

U.S. APPLICATION NO. 09/719874		INTERNATIONAL APPLICATION NO. PCT/EP 99/04370		ATTORNEY'S DOCKET NUMBER IN-5439	
17. <input checked="" type="checkbox"/> The following fees are submitted				CALCULATIONS	
<b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b> Neither international preliminary examination fee (37 CFR 1.482) Nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO.....				\$970.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO.....				\$840.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.44(a)(2)) paid to USPTO.....				\$690.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4).....				\$670.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) .....				\$ 96.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$840.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than 20 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$130.00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	28 - 20 =	08	X \$18.00	\$162.00	
Independent claims	01- 03 =		X \$80.00	\$	
Multiple dependent claims(s) (if applicable)			+ \$260.00	\$	
TOTAL OF ABOVE CALCULATION =				\$1,132.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				\$	
SUBTOTAL =				\$1,132.00	
Processing fee of \$130.00 for furnishing the English translation later than 20 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$1,132.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$	
TOTAL FEES ENCLOSED =				\$1,132.00	
				Amount to be: refunded	\$
				Charged	\$1,132.00
a. <input type="checkbox"/> A check in the amount of \$_____ to cover the above fees is enclosed.					
b. <input checked="" type="checkbox"/> Please charge my Deposit Account No. 23-3425 in the amount of \$1,132.00 to cover the above fees A triplicate copy of this sheet is enclosed.					
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 23-3425. A triplicate copy of this sheet is enclosed.					
NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO: BASF CORPORATION Patent Department 26701 Telegraph Road Southfield, Michigan 48034-2442 (248) 948-2020			SIGNATURE  Mary E. Golota Name 36,814 REGISTRATION NUMBER		

09/719874

JUST Rec'd PCT/PTO 19 DEC 2000

PATENT

(Practitioner's Docket No. IN- 5439)

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Application of

Hans-Ulrich MORITZ, Sabine  
KOSSAK, Jessica LANGENBUCH,  
Heinz-Peter RINK and Werner Alfons  
JUNG

Serial No.: This application is a  
National Phase of Patent Application  
PCT/EP 99/04370 filed June 23, 1999.

Filed: December 18, 2000

For: TAYLOR REACTOR FOR  
MATERIALS CONVERSION IN THE  
COURSE OF WHICH A CHANGE IN  
VISCOSITY  $\nu$  OF THE REACTION  
MEDIUM OCCURS

Group Art Unit: Not Assigned

Examiner: Not Assigned

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with the United States Postal Service in an envelope as "Express Mail  
Post Office to Addressee" Mailing Label No. EK8949245952US  
addressed to the Assistant Commissioner for Patents, Washington,  
D.C. 20231 on December 18, 2000.

  
Marjorie Ellis

**PRELIMINARY AMENDMENT UNDER 37 CFR § 1.115**

Hon. Commissioner of Patents and Trademarks  
Washington, D.C.

Sir:

This preliminary amendment is submitted with the application for  
entry into the U.S. National Phase under Chapter II. This application is  
based on PCT/EP99/04370 filed on June 23, 1999.

In connection with the filing of this National Phase application,  
please make the following preliminary amendments.

IN THE SPECIFICATION:

Please delete the titles "Taylor Reactor For Materials Conversion Involving A Change In Viscosity  $\nu$  Of The Reaction Medium" and substitute therefor --Taylor Reactor For Materials Conversion In The Course Of Which A Change In Viscosity  $\nu$  Of The Reaction Medium Occurs--.

IN THE CLAIMS:

1. (Amended) A Taylor reactor for conducting material conversions, [having] comprising:

- a) an annular reactor volume defined by an external reactor wall, [(1) located within which there is] a concentrically or eccentrically disposed rotor [(2)], a reactor floor, [(3)] and a reactor lid [(4)], [which together define the annular reactor volume (5),]
- b) at least one means [(6)] for metered addition of reactants into the annular reactor volume, and
- c) a means [(7)] for the discharge of product from the annular reactor volume,

wherein

- d) during [the] a conversion within the annular reactor volume there is a change in [the] a viscosity  $\nu$  of [the] a reaction medium and
- e) one or more of the reactor wall [(1)] and [or] the rotor [(2)] are [or is] geometrically designed [in] such [a way] that the conditions for Taylor vortex flow are met over essentially the entire reactor length [in] of the annular reactor volume [(5)].

2. (Amended) The Taylor reactor [as claimed in] of claim 1, wherein the external reactor wall [(1)] and the rotor [(2)] rotate in the same direction,

the angular velocity of the rotor [(2)] being greater than that of the external reactor wall [(1), or wherein the external reactor wall (1) is stationary while the rotor (2) rotates].

3. (Amended) The Taylor reactor [as claimed in] of claim 1 [or 2], wherein the external reactor wall [(1)] and the rotor [(2)] have an essentially circular circumference over the entire reactor length, as viewed in cross section.

4. (Amended) The Taylor reactor [as claimed in any] of claim[s] 1[ to 3], which is mounted vertically, the reaction medium being moved against gravity.

5. (Amended) The Taylor reactor [as claimed in any] of claim[s] 1[ to 4], wherein the rotor [(2)] is mounted centrically.

6. (Amended) The Taylor reactor [as claimed in any] of claim[s] 1[ to 5], wherein the means [(7)] for the discharge of the product[s] is disposed at the highest point of the reactor lid[ (4)].

7. (Amended) The Taylor reactor [as claimed in any] of claim[s] 1[ to 6], wherein one or more of the external reactor wall and[/or] the rotor (2) are [or is ]geometrically designed [in] such [a way] that [the]an annular gap widens in the flow direction.

8. (Amended) The Taylor reactor [as claimed in] of claim 7, wherein the circumference of the external reactor wall (1) increases [as seen] in the flow direction[, the circumference of the rotor (2) remaining constant, likewise increasing, or reducing].

9. (Amended) The Taylor reactor [as claimed in] of claim 7[ or 8], wherein the external reactor wall [(1)] has the form of a single frustum[ or is composed of a plurality of frusta].

10. (Amended) The Taylor reactor [as claimed in any] of claim[s] 1[ to 6], wherein one or more of the external reactor wall [(1)] and[/or] the rotor[(2)] are [or is] geometrically designed [in] such [a way] that [the] an annular gap narrows in the flow direction.

11. (Amended) The Taylor reactor [as claimed in] of claim 10, wherein the circumference of the external reactor wall (1) reduces [as seen] in the flow direction[, the circumference of the rotor (2) remaining constant, increasing, and likewise reducing].

12. (Amended) The Taylor reactor [as claimed in] of claim 10[ or 11], wherein the external reactor wall [(1)] has the form of a single frustum[ or is composed of a plurality of frusta].

13. (Amended) A process for converting substances, comprising converting a substance in the Taylor reactor of claim 1,

wherein under the conditions of Taylor vortex flow, [in which the] a  
viscosity  $v$  of [the] a reaction medium increases in the course of [the] a  
reaction[, under the conditions of Taylor vortex flow, which is conducted  
using a Taylor reactor as claimed in any of claims 1 to 9].

14. (Amended) The process [as claimed in] of claim 13, wherein a first  
reaction takes place in [the] a first flow- traversed subsection of the Taylor  
reactor and one or more additional [a second, third, etc.] reactions take[s]  
place in one or more additional [a second or further] subsections [-] as  
viewed in an [the] axial flow direction downstream of at least one further  
means [(6)] for meter[ing]ed [in] addition of reactants[ and/or catalysts].

15. (Amended) [The use of the process as claimed in claim 13 or 14] A  
process for preparing addition polymers, copolymers, block copolymers and  
graft copolymers, polycondensation products and polyaddition products,  
core/shell latices, polymer dispersions, products of polymer- analogous  
reactions such as the esterification, amidation or urethanization of polymers  
containing side groups suitable for such reactions, olefinically unsaturated  
materials curable with electron beams or ultraviolet light, or mesophases,  
comprising using the process of claim 13.

16. (Amended) A process for converting substances, comprising  
converting a substance in the Taylor reactor of claim 1,  
wherein under the conditions of Taylor vortex flow, [in which the] a  
viscosity  $v$  of [the] a reaction medium falls in the course of [the] a reaction[,

under the conditions of Taylor vortex flow, which is conducted using a Taylor reactor as claimed in any of claims 1 to 6 and 10 to 12].

17. (Amended) The process [as claimed in] of claim 16, wherein a first reaction takes place in [the] a first flow- traversed subsection of the Taylor reactor and [a second, third, etc.] one or more additional reactions take[s] place in [a second or further] one or more additional subsections [-] as viewed in [the] an axial flow direction [-] downstream of at least one further means [(6)] for meter[ing] ed addition of [in] reactants[ and/or catalysts].

18. (Amended) A process for the breakdown of high molecular mass comprising using t[T]he [use of the] process [as claimed in] claim 16[ or 17 for the breakdown of substances of high molecular mass].

19. (Amended) A process for making moldings, paints, adhesives and other coating materials and films, comprising using as components thereof, substances prepared by the process of claim 13[The use of the substances prepared by the process as claimed in claim 13 or 14 as components of moldings, paints, adhesives and other coating materials, and of films].

20. (New) The Taylor reactor of claim 1, wherein the external reactor wall is stationary while the rotor rotates.

21. (New) The Taylor reactor of claim 8, wherein the circumference of rotor (2) remains constant.



22. (New) The Taylor reactor of claim 8, wherein the circumference of rotor (2) increases.

23. (New) The Taylor reactor of claim 8, wherein the circumference of rotor (2) decreases.

24. (New) The Taylor reactor of claim 7, wherein the external reactor wall is composed of a plurality of frusta.

25. (New) The Taylor reactor of claim 11, wherein the circumference of the rotor remains constant.

26. (New) The Taylor reactor of claim 11, wherein the circumference of the rotor increases.

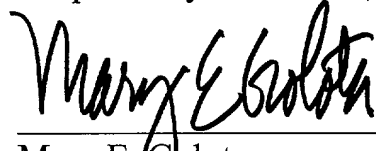
27. (New) The Taylor reactor of claim 11, wherein the circumference of the rotor decreases.

28. (New) The Taylor reactor of claim 12, wherein the external reactor wall is composed of a plurality of frusta.

### **REMARKS**

Upon entry of the present amendment claims 1-28 will be pending in the application. Claims 1-19 have been amended in accordance with the requirements of U.S. patent practice. New claims 20-28 add no new matter, as these claims contain subject matter deleted from claims 1-19. Applicants respectfully request entry of the preliminary amendment.

Respectfully Submitted,



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PAT 98111 PCT  
BASF Coatings AG

June 16, 1999

**Taylor reactor for conversions involving a change in  
viscosity  $\nu$  of the reaction medium**

The present invention relates to a novel Taylor reactor  
5 for physical and/or chemical conversions in whose  
course there is a change in the viscosity  $\nu$  of the  
reaction medium. The present invention further relates  
to a novel process for conversion which is accompanied  
by a change in viscosity of the reaction medium under  
10 the conditions of Taylor vortex flow. The invention  
additionally relates to substances produced using the  
novel process in the novel Taylor reactor, and to their  
use.

15 Taylor reactors, which serve to convert substances  
under the conditions of Taylor vortex flow, are known.  
They consist essentially of two coaxial concentric  
cylinders of which the outer is fixed while the inner  
rotates. The reaction space is the volume formed by the  
20 gap between the cylinders. Increasing angular velocity  
 $\omega_i$  of the inner cylinder is accompanied by a series of  
different flow patterns which are characterized by a  
dimensionless parameter, known as the Taylor number  $Ta$ .  
As well as the angular velocity of the stirrer, the  
25 Taylor number is also dependent on the kinematic  
viscosity  $\nu$  of the fluid in the gap and on the  
geometric parameters, the external radius of the inner  
cylinder  $r_i$ , the internal radius of the outer cylinder

$r_o$  and the gap width  $d$ , the difference between the two radii, in accordance with the following formula:

$$Ta = \omega_i r_i d v^{-1} (d/r_i)^{1/2} \quad (I)$$

5

where  $d = r_o - r_i$ .

At low angular viscosity, the laminar Couette flow, a simple shear flow, develops. If the rotary speed of the inner cylinder is increased further, then, above a critical level, alternately contrarotating vortices (rotating in opposition) occur, with axes along the peripheral direction. These vortices, called Taylor vortices, are rotationally symmetric, possess the geometric form of a torus (Taylor vortex ring), and have a diameter which is approximately the same size as the gap width. Two adjacent vortices form a vortex pair or a vortex cell.

The basis of this behavior is the fact that, in the course of rotation of the inner cylinder with the outer cylinder at rest, the fluid particles that are near to the inner cylinder are subject to a greater centrifugal force than those at a greater distance from the inner cylinder. This difference in the acting centrifugal forces displaces the fluid particles from the inner to the outer cylinder. The centrifugal force acts counter to the viscosity force, since for the motion of the fluid particles it is necessary to overcome the

friction. If there is an increase in the rotary speed, there is also an increase in the centrifugal force. The Taylor vortices are formed when the centrifugal force exceeds the stabilizing viscosity force.

5

If the Taylor reactor is provided with an inlet and outlet and is operated continuously, the result is a Taylor vortex flow with a low axial flow. Each vortex pair passes through the gap, with only a low level of  
10 mass transfer between adjacent vortex pairs. Mixing within such vortex pairs is very high, whereas axial mixing beyond the pair boundaries is very low. A vortex pair may therefore be regarded as a stirred tank in which there is thorough mixing. Consequently, the flow  
15 system behaves as an ideal flow tube in that the vortex pairs pass through the gap with constant residence time, like ideal stirred tanks.

The Taylor reactors known to date may be used for  
20 emulsion polymerization. In this context, reference may be made by way of example to patents DE-B-1 071 241 and EP-A-0 498 583 or to the article by K. Kataoka in Chemical Engineering Science 50 (1995) 9, 1409 to 1416. They are also suitable for electrochemical processes,  
25 in which case the cylinders function as electrodes. In this context, reference may be made to the articles by S. Cohen and D. M. Maron in Chemical Engineering Journal 27 (1983) 2, 87 to 97, and by Couret and

Legrand in *Electrochimia Acta* 26 (1981) 7, 865 to 872,  
and 28 (1983) 5, 611 to 617.

It is also known to use the Taylor reactors as  
5 photochemical reactors, in which the light source is  
located in the inner cylinder (cf. in this respect the  
articles by Szechowski in *Chemical Engineering Science*  
50 (1995) 20, 3163 to 3173, by Haim and Pismen in  
*Chemical Engineering Science* 49 (1994) 8, 1119 to 1129,  
10 and by Karpel Vel Leitner in *Water Science and*  
*Technology* 35 (1997) 4, 215 to 222).

Their use as bioreactors (cf. in this respect the  
article by Huang and Liu in *Water Science and*  
15 *Technology* 28 (1994) 7, 153 to 158) or as flocculation  
reactors for wastewater purification (cf. in this  
respect the article by Grohmann in BMFT-FB-T 85-070,  
1985) has also been described.

20 With all of these known conversions in Taylor reactors,  
there is absolutely no, or no significant, change in  
the viscosity  $\nu$  of the fluid. As a result, given a  
strictly cylindrical geometry of the inner and outer  
cylinders of the Taylor reactor, the conditions for  
25 Taylor vortex flow are maintained over the entire  
length of the annular gap, i.e., of the total reactor  
volume.

If, however, the known Taylor reactors are to be used for conversions where there is a substantial change in the viscosity  $\nu$  of the fluid in the axial flow direction as conversion progresses, the Taylor vortices disappear or are not even formed. In that case, Couette flow, a concentric, laminar flow, is observed in the annular gap, and there is an unwanted change in the mixing and flow conditions within the Taylor reactor. In this operating state it exhibits flow characteristics which are comparable with those of the laminarly flow-traversed tube, which is a considerable disadvantage. For example, in the case of addition polymerization in bulk or in solution, there is an undesirably broad molecular mass distribution and chemical polydispersity of the polymers. Moreover, the poor reaction routine may result in considerable amounts of residual monomers, which then have to be discharged from the Taylor reactor. However, there may also be instances of coagulation and polymer deposition, which in some cases may even lead to blockage of the reactor or of the product outlet. Undesired technical effects of this kind, or of a similar kind, also accompany the thermal degradation of the high molecular mass materials such as polymers, etc. Overall, it is no longer possible to obtain the desired products, such as polymers of very narrow molecular mass distribution, but only those whose profile of properties does not meet requirements.

It is an object of the present invention to propose a new Taylor reactor from which the disadvantages of the prior art are now absent and which instead makes it possible to conduct a simple, elegant, trouble-free and  
5 high-yield conversion of substances even when this conversion is accompanied by a substantial change in the viscosity  $\nu$  of the reaction medium.

A further object of the present invention is to find a  
10 new process for material conversion under the conditions of Taylor vortex flow in the course of which there is a substantial change in the viscosity  $\nu$  of the fluid in the annular gap, i.e., of the reaction medium.

15 Accordingly, we have found the novel Taylor reactor for conducting material conversions, having

- a) an external reactor wall (1) located within which there is a concentrically or  
20 eccentrically disposed rotor (2), a reactor floor (3) and a reactor lid (4), which together define the annular reactor volume (5),
- b) at least one means (6) for metered addition of reactants, and
- 25 c) a means (7) for the discharge of product,

where

- d) during the conversion there is a change in the viscosity  $\nu$  of the reaction medium and



- e) the reactor wall (1) and/or the rotor (2) are or is geometrically designed in such a way that the conditions for Taylor vortex flow are met over essentially the entire reactor length in the reactor volume (5).

In the text below, the novel Taylor reactor for conducting conversions is referred to for short as the "Taylor reactor of the invention". Correspondingly, the novel process for converting materials under the conditions of Taylor vortex flow is referred to as the "process of the invention".

In the light of the prior art, it was surprising and unforeseeable for the skilled worker that by virtue of the geometric design of the reactor wall (1) and/or of the rotor (2), with axial flow of the reaction medium through the Taylor reactor, it is possible to retain the conditions of Taylor vortex flow over the entire reactor length even when there is a substantial change in the viscosity  $\nu$  of the reaction medium in the course of its passage through the annular gap.

The change in the viscosity  $\nu$  of the reaction medium may, in accordance with the invention, involve an increase or a decrease. Both changes may amount to several powers of ten in any individual case. An increase of this magnitude in the viscosity  $\nu$  occurs, for example, in the course of addition polymerization

in bulk or in solution. Conversely, a decrease of such magnitude in the viscosity  $\nu$  results in the course of depolymerization. Even under these particularly demanding technical conditions, however, Taylor vortex  
5 flow is maintained in the Taylor reactor of the invention.

In the Taylor reactor of the invention, the external reactor wall (1) is stationary while the rotor (2)  
10 rotates. In a further variant, the external reactor wall (1) and the rotor (2) rotate in the same direction, the angular velocity of the rotor (2) being greater than the angular velocity of the external reactor wall (1). In another variant, the external  
15 reactor wall (1) and the rotor (2) rotate in opposite directions. Accordingly, the variant comprising the stationary external reactor wall (1) constitutes a special case of the second and third variant, which is, however, preferred owing to the simple construction and  
20 the considerably greater ease of technical monitoring.

The external reactor wall (1) and the rotor (2) have an essentially circular circumference over the entire reactor length, as viewed in cross section. In the  
25 context of the present invention, the term "essentially circular" means strictly circular, oval, elliptical or triangular, rectangular, square, pentagonal, hexagonal or polygonal with rounded angles. For reasons of greater facility of production, simplicity of

construction, and the significantly simpler maintenance of constant conditions over the entire reactor length, a strictly circular circumference is of advantage.

5 In accordance with the invention, the internal wall of the external reactor wall (1) and/or the surface of the rotor (2) are or is smooth or rough, i.e., the surfaces in question have a low or high surface roughness. Additionally or alternatively, the internal wall of the  
10 external reactor wall (1) and/or the surface of the rotor (2) have or has a relieflike radial and/or axial, preferably radial, surface profile. If there is a radial surface profile, it is advantageously of approximately or precisely the same dimensions as the  
15 Taylor vortex rings.

In accordance with the invention it is preferred for the internal wall of the external reactor wall (1) and the surface of the rotor (2) to be smooth, in order to  
20 prevent dead corners into which gas bubbles or reactants and products might settle.

Viewed in the lengthwise direction, the Taylor reactor of the invention is mounted vertically, horizontally,  
25 or in a position between these two directions. In accordance with the invention, vertical mounting is advantageous. If the Taylor reactor of the invention is not mounted horizontally, it may be traversed by the reaction medium flowing against gravity, from bottom to

top, or with gravity, from top to bottom. In accordance with the invention it is of advantage if the reaction medium is moved counter to gravity.

5 The rotor (2) of the Taylor reactor of the invention is mounted centrally or eccentrically. That is, its longitudinal axis coincides (centrically) or not (eccentrically) with the longitudinal axis of the external reactor wall (1). In the latter case, the  
10 longitudinal axis of the rotor (2) may lie parallel to the longitudinal axis of the external reactor wall (1) or may be inclined at an acute angle relative to it. In accordance with the invention it is of advantage if the rotor (2) is mounted centrally.

15

As further essential constituents, the Taylor reactor of the invention comprises a reactor floor (3) and a reactor lid (4), which together with the external reactor wall (1) and the rotor (2) define the annular  
20 reactor volume (5) and provide pressuretight and gastight sealing thereof with respect to the outside. Suitable reactor floors (3) and reactor lids (4) are customary and known; by way of example, reference may be made to patents DE-B-1 071 241 and EP-A-0 498 583.

25

As a further essential constituent, the Taylor reactor of the invention further comprises at least one customary and known means (6) for metered addition of reactants. An example of an appropriate means (6) is a

nozzle of appropriate cross section. The means (6) may be installed in the reactor floor (3), the reactor lid (4), the external reactor wall (1), or the rotor (2). Additionally, the Taylor reactor of the invention may  
5 comprise at least one further means (6) disposed at the same height as the first or offset from it in the flow direction. A further such means (6) is especially advantageous when there is to be subsequent metering of reactants and/or catalysts. Normally, the means (6) are  
10 connected via appropriate lines to metering pumps, reservoir vessels, etc.

A further essential constituent of the Taylor reactor of the invention is the means (7) for the discharge of  
15 the products. Depending on the circumstances, the means (7) is installed in the reactor floor (3), the external reactor wall (1), or the reactor lid (4). It too is usually connected via appropriate lines to metering pumps, reservoir vessels, etc. In accordance with the  
20 invention it is of particular advantage to dispose the means (7) at the top end of the Taylor reactor of the invention, with particular preference being given to the highest point, since with this configuration the formation of a gas phase is prevented. This is  
25 particularly necessary when there is a risk of formation of explosive mixtures or of the deposition of solids such as polymers from the gas phase.

The constituents of the Taylor reactor of the invention, especially external reactor wall (1), the rotor (2), the reactor floor (3), the reactor lid (4), the means (6) for metered addition of reactants, and  
5 the means (7) for the discharge of products, may consist of any of a wide variety of appropriate materials. Examples of suitable materials are plastic, glass or metals such as stainless steel, nickel or copper. The individual constituents may each have been  
10 produced from different materials. The selection of the materials is guided by the intended use of the Taylor reactor of the invention and by the specific reaction conditions and may therefore be carried out in a simple manner by the skilled worker. Where, for example, the  
15 Taylor reactor of the invention is to be used as a photoreactor, the rotor (2) may consist of glass which is transparent to actinic light. If there is to be visual monitoring of the Taylor vortex rings and their axial motion during the conversions, it is of advantage  
20 in accordance with the invention to manufacture the external reactor wall (1) from glass or transparent plastic. Such Taylor reactors of the invention are also outstandingly suitable for conducting preliminary experiments. Otherwise, it is of advantage in  
25 accordance with the invention to use stainless steel.

The rotor (2) is connected to an infinitely adjustable drive in a customary and known manner, by way of a magnetic coupling, for example.

Apart from the essential constituents described in detail above, the Taylor reactor of the invention may also comprise customary and known means serving for  
5 heating and/or cooling or for measuring pressure, temperature, concentration, viscosity, and other physicochemical variables, and may also be connected to customary and known mechanical, hydraulic and/or electronic measurement and control devices.

10

All of these constituents of the Taylor reactor of the invention are connected to one another in such a way that the reaction medium is enclosed in a pressuretight and gastight way and is appropriately thermally  
15 conditioned. Thermal conditioning takes place advantageously in one or more temperature zones which are operated in cocurrent or in countercurrent.

Where the Taylor reactor of the invention is used for  
20 the process of the invention in which the viscosity  $v$  of the reaction medium increases sharply in the flow direction, the external reactor wall (1) and/or the rotor (2) are geometrically designed in such a way that the annular gap widens in the flow direction.

25

In this case, in accordance with the invention, the annular gap - viewed in longitudinal section through the Taylor reactor of the invention - may widen continuously or discontinuously in accordance with any

desired suitable mathematical function. The extent of the widening is guided by the expected increase in the viscosity of the reaction medium in the flow direction and may be estimated by the skilled worker on the basis  
5 of the Taylor formula and/or determined by means of simple preliminary experiments.

Examples of suitable mathematical functions in accordance with which the circumference of the external  
10 reactor wall (1) and/or of the rotor (2) increase or increases - viewed in longitudinal section through the Taylor reactor of the invention - are straight lines, at least two straight lines which intersect one another at an obtuse angle, hyperbolas, parabolas, e functions,  
15 or combinations of these functions with continuous or discontinuous transitions between them.

First, the widening may be achieved by an increase in the circumference of the external reactor wall (1) as  
20 seen in the flow direction, the circumference of the rotor (2) remaining constant, likewise increasing, or reducing. Secondly, it may be achieved by keeping the diameter of the external reactor wall (1) constant while reducing the circumference of the rotor (2). In  
25 view of the fact that if the circumference of the rotor (2) is reduced the area for the transfer of the frictional forces becomes smaller and smaller and, therefore, the rotor (2) would have to rotate faster and faster, preference is given to those variants of



the invention wherein the circumference of the rotor (2) remains constant or likewise increases.

Advantageous Taylor reactors of the invention have a  
5 conical external reactor wall (1) which, accordingly, has the form of a single frustum or is composed of a plurality of frusta. The frustum or frusta may have a pillow-shaped or barrel-shaped distortion. However, undistorted frusta are particularly preferred.

10

Advantageous Taylor reactors of the invention further comprise a conical or cylindrical rotor (2). Regarding the form of the conical rotor (2), the comments made in the preceding paragraph apply mutatis mutandis.  
15 Similarly, the cylindrical rotor (2) may have a pillow-shaped or barrel-shaped distortion. In accordance with the invention, undistorted cylindrical rotors (2) are used with particular preference.

20 Where the Taylor reactor of the invention is used for the process of the invention in which the viscosity  $\nu$  of the reaction medium decreases sharply in the flow direction, the external reactor wall (1) and/or the rotor (2) may be geometrically designed in such a way  
25 that the annular gap narrows in the flow direction.

In this case, in accordance with the invention, the annular gap - viewed in longitudinal section through the Taylor reactor of the invention - may narrow

continuously or discontinuously in accordance with any desired suitable mathematical function. The extent of the narrowing is guided by the expected decrease in the viscosity of the reaction medium in the flow direction  
5 and may be estimated by the skilled worker on the basis of the Taylor formula (I) and/or determined by means of simple preliminary experiments.

Examples of suitable mathematical functions in  
10 accordance with which the circumference of the external reactor wall (1) and/or of the rotor (2) decrease or decreases - viewed in longitudinal section through the Taylor reactor of the invention - are straight lines, at least two straight lines which intersect one another  
15 at an obtuse angle, hyperbolas, parabolas, e functions, or combinations of these functions with continuous or discontinuous transitions between them.

First, the narrowing may be achieved by a reduction in  
20 the circumference of the external reactor wall (1) as seen in the flow direction, the circumference of the rotor (2) remaining constant, increasing or likewise reducing. Secondly, it may be achieved by keeping the diameter of the external reactor wall (1) constant  
25 while increasing the circumference of the rotor (2). In view of the fact that if the circumference of the rotor (2) is reduced the area for the transfer of the frictional forces becomes smaller and smaller and, therefore, the rotor (2) would have to rotate faster

and faster, preference is given to those variants of the invention wherein the circumference of the rotor (2) remains constant or likewise increases.

5 Here too, advantageous Taylor reactors of the invention have a conical external reactor wall (1) which, accordingly, has the form of a single frustum or is composed of a plurality of frusta. The frustum or frusta may have a pillow-shaped or barrel-shaped  
10 distortion. However, undistorted frusta are particularly preferred.

Advantageous Taylor reactors of the invention further comprise a conical or cylindrical rotor (2). Regarding  
15 the form of the conical rotor (2), the comments made in the preceding paragraph apply mutatis mutandis. Similarly, the cylindrical rotor (2) may have a pillow-shaped or barrel-shaped distortion. In accordance with the invention, undistorted cylindrical rotors (2) are  
20 used with particular preference.

The Taylor reactor of the invention is ideally suited to conducting the process of the invention. The process of the invention may be operated continuously or  
25 batchwise; its particular advantages, however, become apparent in the case of continuous operation.

To conduct the process, the reactant or reactants is or are metered continuously to the annular reactor volume

(5) by way of at least one means (6). The resultant products are removed continuously from the Taylor reactor of the invention by way of the means (7) and are worked up appropriately.

5

In the process of the invention, the residence time in the reactor is between 0.5 minutes and 5 hours, preferably 2 minutes and 3 hours, with particular preference 10 minutes and 2 hours, and in particular 15  
10 minutes and 1.5 hours. The appropriate residence time for the conversion in question may be determined by the skilled worker on the basis of simple preliminary experiments or estimated on the basis of kinetic data.

15 The pressure in the annular reaction body (5) is from 0 to 200 bar, and so the process of the invention may also be performed with liquefied or supercritical gases, such as supercritical carbon dioxide. Preferably, the pressure is from 0.5 to 100 bar, in  
20 particular from 0.5 to 50 bar. Where the process of the invention is conducted at a relatively high pressure, the Taylor reactor of the invention, and its incoming and outgoing lines, must be given a pressure-tight design in order to meet the safety provisions.

25

The process of the invention is conducted at temperatures between -100 and 500°C. For this purpose, the Taylor reactor of the invention is equipped with suitable, customary and known cooling and/or heating

means. Preferably, the reaction temperatures are between -10 and 300°C, in particular 50 and 250°C. The temperature appropriate for the conversion in question may be determined by the skilled worker on the basis of  
5 simple preliminary experiments or estimated on the basis of known thermodynamic data.

Advantageously, the Taylor number  $Ta$  of the reaction medium or of the fluid is from 1 to 10,000, preferably  
10 from 5 to 5000, and in particular from 10 to 2500. At the same time the Reynolds number, which is defined by equation (II) below, should be from 1 to 10,000.

$$Re = vd/v \text{ (II)}$$

15

where  $v$  is the axial velocity and

$d = r_o - r_i$  ( $r_i$  = external radius of the inner cylinder;  
 $r_o$  = internal radius of the outer cylinder, and  $d$  = gap  
width).

20

In the process of the invention, there is a change in the viscosity  $v$  of the reaction medium. This viscosity  $v$  may increase or fall. The change may amount of several powers of ten, without disrupting the conduct  
25 of the process of the invention. All that is needed is to ensure that the annular gap of the Taylor reactor of the invention widens or narrows in correspondence with the change in viscosity in the course of the conversions, so that Taylor vortex flow is maintained

in the entire reactor. The course of the change in velocity may be determined by the skilled worker on the basis of simple preliminary experiments.

5 A very particular advantage of the Taylor reactor of the invention and of the process of the invention is to link the spatial succession in the Taylor reactor with the temporal succession of batchwise or semicontinuous (metering) processes. The Taylor reactor of the  
10 invention and the process of the invention therefore provide the advantage of a continuous, quasi-"single-stage" process, so that a first reaction may take place in the first flow-traversed subsection of the Taylor reactor and a second, third, etc. reaction in a second  
15 or further subsection - as viewed in the axial flow direction - downstream of one further means (6) for metering in reactants and/or catalysts.

Examples of conversions for which the process of the  
20 invention may be employed for particular advantage are, in particular, the buildup or breakdown of substances of low and high molecular mass, such as the polymerization of monomers in bulk, solution, emulsion or suspension, or by precipitation polymerization, on  
25 the one hand, and the depolymerization of the resultant polymers, or other high molecular mass materials, on the other. In the context of the present inventions, the term "polymerization" embraces not only addition polymerization, copolymerization and block

copolymerization but also polycondensation and polyaddition.

Further examples of such conversions are

5

- polymer-analogous reactions, such as the esterification, amidation or urethanization of polymers containing side groups suitable for such reactions,
- 10 - the preparation of olefinically unsaturated materials curable using electron beams or ultraviolet light,
- the preparation of polyurethane resins and modified polyurethane resins such as acrylated polyurethanes,
- 15 - the preparation of (poly)ureas or modified (poly)ureas,
- the molecular weight buildup of compounds terminated by isocyanate groups,
- 20 - or reactions which lead to the formation of mesophases, as described, for example, by Antonietti and Göltner in the article "Überstruktur funktioneller Kolloide: eine Chemie im Nanometerbereich [Superstructure of functional colloids: A chemistry in the nanometer range]" in
- 25 Angewandte Chemie 109 (1997) 944 to 964 or by Ober and Wengner in the article "Polyelectrolyte-Surfactant Complexes in the Solid State: Facile

Building Blocks for Self-Organizing Materials" in  
Advanced Materials, 9 (1997) 1, 17 to 31.

5 With very particular advantage, the process of the  
invention is employed for the polymerization of  
olefinically unsaturated monomers, since in this case  
the particular advantages of the Taylor reactor of the  
invention and of the process of the invention are  
manifested with particular clarity.

10

Accordingly, the process of the invention is used with  
particular preference for the preparation of copolymers  
of chemically uniform composition. In this utility, the  
more rapidly polymerizing comonomer or comonomers is or  
15 are metered in by way of means (6) disposed in  
succession in the axial direction, so that the  
comonomer ratio is kept constant over the entire length  
of the reactor.

20 The process of the invention is also used with  
particular preference for graft copolymerization. In  
this utility, in the first subsection of the Taylor  
reactor of the invention, the backbone polymer is  
prepared, after which at least one comonomer which  
25 forms the graft branches is metered in by way of at  
least one further means (6), offset in the axial  
direction. Subsequently, in accordance with the  
invention, the comonomer or comonomers is or are  
grafted onto the backbone polymer in at least one



further subsection of the Taylor reactor of the invention. Where two or more comonomers are used, they may be metered in individually by way of one means (6) in each case or as a mixture, by one or more means (6).

5 Where at least two comonomers are metered in individually and in succession by at least two means (6), it is even possible to prepare graft branches which per se are block copolymers, in a particularly simple and elegant manner.

10

Of course, this concept as described above may also be used to prepare block copolymers per se.

Analogously, the preparation of core/shell lattices may  
15 be realized in a particularly simple and elegant manner with the aid of the process of the invention. Initially, in the first subsection of the Taylor reactor of the invention, the core is prepared by polymerizing at least one monomer. By way of at least  
20 one further means (6), at least one further comonomer is metered in and the shell is polymerized onto the core in at least one further subsection. In this way it is possible to apply a plurality of shells to the core.

25 The preparation of polymer dispersions may also take place with the aid of the process of the present invention. For example, at least one monomer in a homogeneous phase, especially in solution, is (co)polymerized in a first subsection of the Taylor

reactor of the invention, after which a precipitant is metered in by way of at least one further means (6), resulting in the polymer dispersions.

- 5 For all applications, the Taylor reactor of the invention has the particular advantage of a large specific cooling area which allows a particularly safe reaction regime.
- 10 Examples of monomers suitable for the process of the invention are acyclic and cyclic, unfunctionalized and functionalized monoolefins and diolefins, vinylaromatic compounds, vinyl ethers, vinyl esters, vinyl amides, vinyl halides, allyl ethers and allyl esters, acrylic
- 15 acid and methacrylic acid and their esters, amides and nitriles, and maleic acid, fumaric acid and itaconic acid and their esters, amides, imides and anhydrides.

Examples of suitable monoolefins are ethylene,

20 propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, cyclobutene, cyclopentene and cyclohexene.

Examples of suitable diolefins are butadiene, isoprene, cyclopentadiene and cyclohexadiene.

25

Examples of suitable vinylaromatic compounds are styrene, alpha-methylstyrene, 2-, 3- and 4-chloro-, -methyl-, -ethyl-, -propyl- and -butyl- and -tert-butylstyrene and -alpha-methylstyrene.

An example of a suitable vinyl compound or of a functionalized olefin is vinylcyclohexanediol.

5 Examples of suitable vinyl ethers are methyl, ethyl, propyl, butyl and pentyl vinyl ether, allyl monopropoxylate, and also trimethylolpropane monoallyl, diallyl and triallyl ether.

10 Examples of suitable vinyl esters are vinyl acetate and vinyl propionate and also the vinyl esters of Versatic acid and of other quaternary acids.

Examples of suitable vinyl amides are N-methyl-, N,N-  
15 dimethyl-, N-ethyl-, N-propyl-, N-butyl-, N-amyl-, N-cyclopentyl- and N-cyclohexylvinylamide and also N-vinylpyrrolidone and epsilon-caprolactam.

Examples of suitable vinyl halides are vinyl fluoride  
20 and vinyl chloride.

Examples of suitable vinylidene halides are vinylidene fluoride and vinylidene chloride.

25 Examples of suitable allyl ethers are methyl, ethyl, propyl, butyl, pentyl, phenyl and glycidyl monoallyl ether.

Examples of suitable allyl esters are allyl acetate and allyl propionate.

Examples of suitable esters of acrylic acid and  
5 methacrylic acid are methyl, ethyl, propyl, n-butyl, isobutyl, n-pentyl, n-hexyl, 2-ethylhexyl, isodecyl, decyl, cyclohexyl, t-butylcyclohexyl, norbornyl, isobornyl, 2- and 3-hydroxypropyl, 4-hydroxybutyl, trimethylolpropane mono-, pentaerythritol mono- and  
10 glycidyl (meth)acrylate. Also suitable are the di-, tri- and tetra(meth)acrylates of ethylene glycol, di-, tri- and tetraethylene glycol, propylene glycol, dipropylene glycol, butylene glycol, dibutylene glycol, glycerol, trimethylolpropane and pentaerythritol.  
15 However, they are used not alone but always in minor amounts together with the monofunctional monomers.

Examples of suitable amides of acrylic acid and methacrylic acid are (meth)acrylamide and also N-  
20 methyl-, N,N-dimethyl-, N-ethyl-, N-propyl-, N-butyl-, N-amyl-, N-cyclopentyl- and N-cyclohexyl(meth)-acrylamide.

Examples of suitable nitriles are acrylonitrile and  
25 methacrylonitrile.

Examples of suitable esters, amides, imides and anhydrides of maleic acid, fumaric acid and itaconic acid are dimethyl, diethyl, dipropyl and dibutyl

maleate, fumarate and itaconate, maleamide, fumaramide  
and itaconamide, N,N'-dimethyl-, N,N,N',N'-tetra-  
methyl-, N,N'-diethyl-, N,N'-dipropyl-, N,N'-dibutyl-,  
N,N'-diamyl-, N,N'-dicyclopentyl and N,N'-dicyclohexyl-  
5 maleamide, -fumaramide and -itaconamide, maleimide,  
fumarimide and itaconimide, and N-methyl-, N-ethyl-, N-  
propyl-, N-butyl-, N-amyl-, N-cyclopentyl- and N-  
cyclohexyl-maleimide, -fumarimide and -itaconimide, and  
also maleic, fumaric and itaconic anhydride.

10

The monomers described above may be polymerized free-  
radically, cationically or anionically. Advantageously,  
they are polymerized free-radically. For this purpose,  
the customary and known inorganic free-radical  
15 initiators may be used, such as hydrogen peroxide or  
potassium peroxodisulfate, or the customary and known  
organic free-radical initiators, such as dialkyl  
peroxides, e.g., di-tert-butyl peroxide, di-tert-amyl  
peroxide and dicumyl peroxide; hydroperoxides, e.g.,  
20 cumene hydroperoxide and tert-butyl hydroperoxide; per  
esters, e.g. tert-butyl perbenzoate, tert-butyl  
perpivalate, tert-butyl per-3,5,5-trimethylhexanoate  
and tert-butyl per-2-ethylhexanoate; bisazo compounds  
such as azobisisobutyronitrile; or C-C initiators such  
25 as 2,3-dimethyl-2,3-diphenyl-butane or -hexane. Also  
suitable, however, is styrene, which initiates  
polymerization thermally even without free-radical  
initiators.

The polymers prepared in accordance with the invention have particular advantages and are therefore outstandingly suitable for all applications as commonly envisaged for substances of high molecular mass of this  
5 kind, such as, for example, the production of moldings. In particular, however, they are suitable as components for paints, adhesives and other coating materials, and also films. In this case, they are used in particular as binders, since the paints, adhesives and other  
10 coating materials, and also the films, which comprise or consist of the binders prepared in accordance with the invention have particularly outstanding performance properties.

15 The particular advantages of the process of the invention are evident in particular from the paints which comprise the binders prepared in accordance with the invention. Depending on their composition, these paints are physically drying or are cured thermally,  
20 with actinic light, especially UV light, or by means of electron beams.

They are present as powder coating materials, powder slurry coating materials, coating materials dissolved  
25 in organic media, or aqueous coating materials. They may comprise color and/or effect pigments. They are used as architectural coatings for the interior and exterior sectors, as coating materials for furniture, windows, coils and other industrial applications, as

automobile finishes for original equipment (OEM), or as automotive refinishes. In the context of their use in the automobile sector, they are suitable as electrodeposition coating materials, surfacers, basecoats, and clearcoats.

In all of these applications, the coating materials comprising the binders prepared in accordance with the invention are superior to the conventional coating materials.

The present invention is illustrated by the drawing (Fig. 1) and the example.

**Fig. 1** Longitudinal section through a Taylor reactor of the invention with a conical external reactor wall (1) for visual monitoring of the Taylor vortex flow

**Example 1**

The chain extension of partially hydrolyzed polyvinyl acetate (polyvinyl alcohol) with glutaraldehyde using a Taylor reactor of the invention and the process of the invention

The chain extension of partially hydrolyzed polyvinyl acetate (hydroxyl group content: 88 mol%; acetate group

content: 12 mol%) was carried out using the Taylor reactor of the invention in accordance with Fig. 1.

The Taylor reactor had a 25 cm high external reactor wall (1) made of glass, of strictly circular circumference, whose circumference and, respectively, diameter increased linearly along the reactor axis as viewed in the flow direction. Thus the minimum diameter of the external reactor wall (1) at the reactor floor (3) was 52 mm and the maximum diameter at the reactor lid (4) was 102 mm. The Taylor reactor of the invention further comprised a linear, centrically mounted, strictly cylindrical rotor (2) made of stainless steel, with a radius of 21 mm. As a result, there was an increase in the gap width  $d$  from 5 mm at the bottom end of the Taylor reactor to 30 mm at the top end. Via a straight shaft (2.1), which passed with sealing through the reactor lid (4), the rotor (2) was connected to an infinitely adjustable stirring motor. The reactor lid (4) and the reactor base (3) were of stainless steel; sealing between them and the corresponding end of the reactor wall (1) was effected by means of customary and known polymer gaskets. The means (6) for metered addition of the reactants and the means (7) for the discharge of product were glass advancers with threads, to which a feed hose and a discharge hose were fastened by means of coupling rings.



The Taylor reactor was fed continuously by way of the means (6) with a mixture of 4 parts of polyvinyl alcohol, 96.16 parts of water and 0.16 parts of glutaraldehyde with a volume flow of 33.3 ml/min.

5

Directly before entry into the Taylor reactor, 42% strength nitric acid was metered into the mixture by way of a separate pump, with a volume flow of 0.16 ml/min. The average residence time in the Taylor reactor was 30 min at a temperature of 22°C. The stirrer speed was 250 rpm. The viscosity of the starting material was 10 mm<sup>2</sup>/s. At the means (7), the solution of the chain extended polyvinyl alcohol had a viscosity of 47 mm<sup>2</sup>/s.

15

The material conversion, i.e., the reaction, was conducted in a total time of 5 h, corresponding to 10 average residence times. Throughout the Taylor reactor, the Taylor vortices and thus the desired mixing and flow conditions were maintained during this period, despite the increase in viscosity. It was therefore possible to conduct the reaction without disruption during the entire period of time.

**Example 2****The preparation of a solution polymer in a Taylor reactor of the invention**

5

A mixture of 15.8 parts of styrene, 16.5 parts of MMA, 11.6 parts of tert-butylcyclohexyl acrylate, 24.7 parts of hydroxypropyl methacrylate, 22.3 parts of Shellsol A, 7.4 parts of xylene, 0.3 part of di-tert-butylperoxide, 0.05 part of tert-butylperoxyethylhexanoate and 1.2 parts of dicumyl peroxide was metered using two pumps into a 200 ml conical stainless steel Taylor reactor with heatable jacket. The starting material was metered in at the reactor floor, while the resultant polymer was taken off continuously at the exit from the reactor, at the top in the reactor wall. The reaction was conducted at a temperature of 160°C and with a stirrer speed of 300 min<sup>-1</sup>. The average residence time of the reaction mixture in the reactor was 30 min. The resultant polymer melt had a solids content of 68.4% (1 h, 130°C) and a viscosity of 3.0 dPas (50% strength in butyl acetate). Measurement of the polymer by gel chromatography gives an  $M_n$  of 3215 and an  $M_w$  of 8081. The glass transition temperature of the polymer was 69°C, determined by means of DSC from the DSC midpoint.

10

15

20

25

**Example 3**

**The preparation of a coating material using the solution polymer of Example 2**

5

3.1 A curing agent solution was prepared by mixing the following components:

	butyl acetate 98%	40.5 parts
10	xylene	4.0 parts
	butyl glycol acetate	6.0 parts
	catalyst solution	
	(as per section 3.3)	1.5 parts
	Desmodur <sup>R</sup> Z4370 <sup>1)</sup>	15.0 parts
15	Desmodur <sup>R</sup> 3390 <sup>2)</sup>	33.0 parts
	solids (% by weight)	42.2 parts

3.2 An adjustment additive was prepared by mixing the following components:

20

	xylene	20.0 parts
	solvent naphtha <sup>3)</sup>	15.0 parts
	mineral spirit 135/180	10.0 parts
	butyl glycol acetate	5.0 parts
25	butyl acetate 98%	50.0 parts

3.3 A catalyst solution was prepared by mixing 1.0 parts of dibutyltin dilaurate and 99 parts of butyl acetate 98%

3.4 A leveling agent solution was prepared by mixing 5.0 parts of a commercial leveling agent based on a polyether-modified methylpolysiloxane (Baysilone<sup>R</sup> OL44<sup>4)</sup>) and 95 parts by xylene.

5 3.5 A stock coating material was prepared by mixing the following components:

	butyl acetate	4.0 parts
	xylene	4.15 parts
10	Tinuvin <sup>R</sup> 292 <sup>5)</sup>	0.95 parts
	Sanduvon <sup>R</sup> VSU <sup>6)</sup>	1.20 parts
	catalyst solution	
	(as per section 3.3)	3.7 parts
	leveling agent solution	
15	(as per section 3.4)	2.0 parts
	triisodecyl phosphite	0.05 part
	solution polymer (from Ex. 2)	70.85 parts
	Macrynal <sup>R</sup> SM513 <sup>7)</sup>	13.1 parts

20 180 parts of the stock coating material as per section 3.5 were mixed with 90 parts of curing agent solution as per section 3.1 and 16.2 parts of adjustment additive as per section 3.2, and the mixture was applied. The processing properties of the coating  
25 material were excellent. The pot life was 4 h. The pendulum attenuation of a 1 week old coating film dried at room temperature was 136 sec.

- 
- <sup>1</sup> commercial polyisocyanate from Bayer AG, based on isophorone diisocyanate, with a solids content of 70%
- <sup>2</sup> commercial polyisocyanate from Bayer AG, based on
- 5 hexamethylene diisocyanate
- <sup>3</sup> commercial aromatic hydrocarbon mixture from Shell GmbH
- <sup>4</sup> commercial leveling agent from Bayer AG
- <sup>5</sup> commercial light stabilizer from Ciba Geigy, based on
- 10 a sterically hindered amine (HALS)
- <sup>6</sup> commercial light stabilizer from Sandoz
- <sup>7</sup> hydroxyl-containing acrylate resin from Bayer AG

The resulting clearcoat was applied over a conventional

15 basecoat of the Glasurit Reihe 55 brand. The coatings obtained by drying at 60°C for 30 minutes had a gloss to DIN 67530 of 87°, measured at a 20° angle. The coatings had a good topcoat appearance.

**What is claimed is:**

1. A Taylor reactor for conducting material conversions, having
  - a) an external reactor wall (1) located within which there is a concentrically or eccentrically disposed rotor (2), a reactor floor (3) and a reactor lid (4), which together define the annular reactor volume (5),
  - b) at least one means (6) for metered addition of reactants, and
  - c) a means (7) for the discharge of product,wherein
  - d) during the conversion there is a change in the viscosity  $\nu$  of the reaction medium and
  - e) the reactor wall (1) and/or the rotor (2) are or is geometrically designed in such a way that the conditions for Taylor vortex flow are met over essentially the entire reactor length in the reactor volume (5).
2. The Taylor reactor as claimed in claim 1, wherein the external reactor wall (1) and the rotor (2) rotate in the same direction, the

angular velocity of the rotor (2) being greater than that of the external reactor wall (1), or wherein the external reactor wall (1) is stationary while the rotor (2) rotates.

5

3. The Taylor reactor as claimed in claim 1 or 2, wherein the external reactor wall (1) and the rotor (2) have an essentially circular circumference over the entire reactor length, as viewed in cross section.

10

4. The Taylor reactor as claimed in any of claims 1 to 3, which is mounted vertically, the reaction medium being moved against gravity.

15

5. The Taylor reactor as claimed in any of claims 1 to 4, wherein the rotor (2) is mounted centrically.

20

6. The Taylor reactor as claimed in any of claims 1 to 5, wherein the means (7) for the discharge of the products is disposed at the highest point of the reactor lid (4).

25

7. The Taylor reactor as claimed in any of claims 1 to 6, wherein the external reactor wall (1) and/or the rotor (2) are or is geometrically designed in such a way that the annular gap widens in the flow direction.

8. The Taylor reactor as claimed in claim 7,  
wherein the circumference of the external  
reactor wall (1) increases as seen in the flow  
direction, the circumference of the rotor (2)  
remaining constant, likewise increasing, or  
reducing.
9. The Taylor reactor as claimed in claim 7 or 8,  
wherein the external reactor wall (1) has the  
form of a single frustum or is composed of a  
plurality of frusta.
10. The Taylor reactor as claimed in any of claims  
1 to 6, wherein the external reactor wall (1)  
and/or the rotor (2) are or is geometrically  
designed in such a way that the annular gap  
narrows in the flow direction.
11. The Taylor reactor as claimed in claim 10,  
wherein the circumference of the external  
reactor wall (1) reduces as seen in the flow  
direction, the circumference of the rotor (2)  
remaining constant, increasing, and likewise  
reducing.
12. The Taylor reactor as claimed in claim 10 or  
11, wherein the external reactor wall (1) has



the form of a single frustum or is composed of a plurality of frusta.

13. A process for converting substances, in which  
5 the viscosity  $v$  of the reaction medium increases in the course of the reaction, under the conditions of Taylor vortex flow, which is conducted using a Taylor reactor as claimed in any of claims 1 to 9.
- 10 14. The process as claimed in claim 13, wherein a first reaction takes place in the first flow-traversed subsection of the Taylor reactor and a second, third, etc. reaction takes place in a  
15 second or further subsection - as viewed in the axial flow direction - downstream of at least one further means (6) for metering in reactants and/or catalysts.
- 20 15. The use of the process as claimed in claim 13 or 14 for preparing addition polymers, copolymers, block copolymers and graft copolymers, polycondensation products and  
25 polyaddition products, core/shell latices, polymer dispersions, products of polymer-analogous reactions such as the esterification, amidation or urethanization of polymers containing side groups suitable for such reactions, olefinically unsaturated materials

curable with electron beams or ultraviolet light, or mesophases.

16. A process for converting substances, in which  
5 the viscosity  $v$  of the reaction medium falls in  
the course of the reaction, under the  
conditions of Taylor vortex flow, which is  
conducted using a Taylor reactor as claimed in  
any of claims 1 to 6 and 10 to 12.
- 10 17. The process as claimed in claim 16, wherein a  
first reaction takes place in the first flow-  
traversed subsection of the Taylor reactor and  
a second, third, etc. reaction takes place in a  
15 second or further subsection - as viewed in the  
axial flow direction - downstream of at least  
one further means (6) for metering in reactants  
and/or catalysts.
- 20 18. The use of the process as claimed in claim 16  
or 17 for the breakdown of substances of high  
molecular mass.
19. The use of the substances prepared by the  
25 process as claimed in claim 13 or 14 as  
components of moldings, paints, adhesives and  
other coating materials, and of films.

## Abstract

A Taylor reactor for conducting material conversions, having an external reactor wall (1) located within which there is a concentrically or eccentrically disposed rotor (2), a reactor floor (3) and a reactor lid (4), which together define the annular reactor volume (5), at least one means (6) for metered addition of reactants, and a means (7) for the discharge of product, wherein during the conversion there is a change in the viscosity  $\nu$  of the reaction medium and the reactor wall (1) and/or the rotor (2) are or is geometrically designed in such a way that the conditions for Taylor vortex flow are met over essentially the entire reactor length in the reactor volume (5).

**Combined Declaration For Patent Application and  
Power of Attorney**Practitioner's Docket No. **IN-5439**

As below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: TAYLOR REACTOR FOR MATERIALS CONVERSION IN THE COURSE OF WHICH A CHANGE IN VISCOSITY  
v OF THE REACTION MEDIUM OCCURS

The specification of which (check only one item below):

<input type="checkbox"/>	is attached hereto
<input type="checkbox"/>	Was filed as United States Application Serial No. <u>0 /</u> on and <u>    </u> . Was amended on <u>                    </u> (if applicable).
<input checked="" type="checkbox"/>	was filed as PCT international application Number <u>PCT/EP99/04370</u> on and <u>23.06.1999</u> was amended under PCT Article 19 on <u>                    </u> (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application is accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code § 119 of any foreign application(s) for patent or inventor's certificate of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating a least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

**PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:**

COUNTRY	A PPLICATION NUMBER	DATE OF FILING DATE/MONTH/YEAR	PRIORITY CLAIMED UNDER 35 UNDER 35 USCX § 119			
German	198 28 742.9	27.06.1998	<input checked="" type="checkbox"/>	YES		NO
				YES		NO
				YES		NO
				YES		NO

I hereby claim the benefit under Title 35, United States Code, Sec. § 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, Sec. § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Sec. § 1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

**PRIOR US APPLICATIONS OR PCT INTERNATIONAL APPLICATION DESIGNATING THE U.S. FOR BENEFIT  
UNDER 35 USC § 120:**

U.S. APPLICATIONS			STATUS (Check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE		PATENTED	PENDING	ABANDONED
PCT APPLICATION DESIGNATING THE U.S.					
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)			

**Combined Declaration Patent Application and  
Power of Attorney (Continued)**Practitioner Docket No. **IN-5439**

**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (List name and registration number).

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Mary E. Golota	Registration No. <u>36,814</u>	Michael P. Brennan	Registration No. <u>30,612</u>
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Karen M. Dellerman	Registration No. <u>33,592</u>	Ryan W. Massey	Registration No. <u>38,543</u>
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**DECLARATION**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

**SIGNATURE(S)**

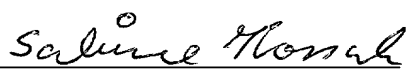

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<b>Combined Declaration Patent Application and Power of Attorney (Continued)</b>				Practitioner Docket No. <b>IN-5439</b>	
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<b>Fernando A. Borrego</b>	Registration No.	34,780	<b>Brian Stegman</b>	Registration No.	<b>30,977</b>
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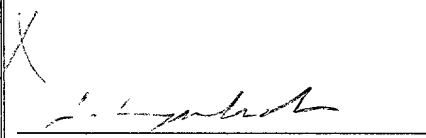
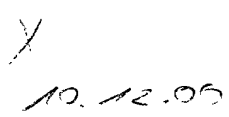
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<b>Combined Declaration Patent Application and Power of Attorney (Continued)</b>		Practitioner Docket No. <b>IN-5439</b>	
<b>POWER OF ATTORNEY:</b> As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (List name and registration number).			
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<b>Fernando A. Borrego</b>	Registration No. 34,780	<b>Brian Stegman</b>	Registration No. 30,977
<b>Karen M. Dellerman</b>	Registration No. 33,592	<b>Ryan W. Massey</b>	Registration No. 38,543
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		or (name and telephone number) <u>Mary E. Golota</u> (248) 948-2020 Fax (248) 948-2093	

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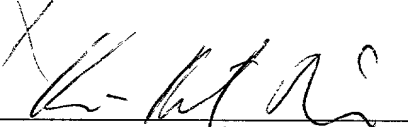
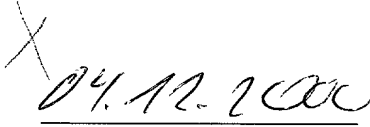
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<b>Combined Declaration Patent Application and Power of Attorney (Continued)</b>		Practitioner's Docket No. <b>IN-5439</b>	
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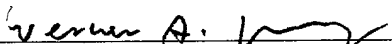


<b>Combined Declaration of Patent Application and Power of Attorney (Continued)</b>				Practitioner's Pocket No. <b>IN-5439</b>	
<b>POWER OF ATTORNEY:</b> As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (List name and registration number).					
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<div style="text-align: center;">Werner Alfons JUNG</div> <div style="display: flex; justify-content: space-between;"> <div style="text-align: center;">   <b>SIGNATURE OF INVENTOR 205</b> </div> <div style="text-align: center;"> <b>TYPED NAME</b> </div> <div style="text-align: center;"> <u>7218100</u>  <b>DATE</b> </div> </div>			